Wax

REPORT ON
THE SECOND MEETING OF THE ARPA PACKET RADIO GROUP
AT COLLINS RADIO, JANUARY 22-23, 1973

The meeting was opened by Bob Kahn with a few comments and a request to the group that each member give a brief summary of what their activities have been since the last meeting and what they plan to present at the meeting. A large number of Packet Radio Notes were available at the meeting and I have brought copies back with me. These notes should be in the pipeline but we probably won't get them for a while. A number of notes did not yet have NIC number assignments.

Dr. Kahn commented that he strongly encourages the use of bibliographies and wants feedback on bibliographies. Presentations by all members of the group took all of Monday and Tuesday morning. This was due to considerable group discussion during each presentation. It was, to say the least, a very active and busy meeting. Tuesday afternoon was used for added discussion and Bob Kahn's summary of what he considered important conceptual issues or tasks. Various members then elected to work on these tasks in groups which would put out PR notes on their results and present them at the next meeting. Kahn feels the next meeting will be a crucial one, where some basic decisions will have to be made in order to meet the deadline of having a system design by the end of the year. The next meeting is now scheduled for March 1 and 2 at IEEE's COMP CON '73 in San Francisco.

Each group gave its summary at the beginning of the meeting as follows:

A. COLLINS

Notes have been prepared on:

1. RF Power Budget (#4)
2. Propagation Characteristics (#14)
3. Antenna Considerations (#13)
4. Safety Standards - Microwave Exposure (#12)
5. Digital Modulation Techniques (#16)
6. Spread - Spectrum Consideration (no number)
7. Solid State RF Sources (#15)

B. NETWORK ANALYSIS CORPORATION

1. Notes have been prepared on Systems Considerations (#5) and Acknowledgement Schemes (#7).
2. The following comments were also made:
   a. They will shortly be outputting a note on the combinatorial aspect of the problem (a combinational model to test reality).
   b. They will be putting out a note on the use of carrier sense. They think that carrier sense will be better than slotted ALOHA.
   c. They are looking at the use of CATV for dense urban areas.
   d. They are looking at the system considerations of one versus many frequencies.
   e. They are looking at the geographical layout problem.

C. STANFORD RESEARCH INSTITUTE

They are looking at:

1. RF problems - capture, power, modulation.
2. Network Analysis and Synthesis. This includes study of the following three models:
   a. MAC Schemes
   b. Flat Model (Traffic Intermixing)
   c. Expandable Hierarchy
3. Implications of satellite radio.
4. Requirements such as traffic density, reservation system schemes, etc.
5. Problems of compressed voice.

D. UCLA

They are working mainly on traffic control and routing schemes. They are looking at the tradeoff between multiple routes and a single route. They have a packet note on Controlled Flooding Using Handover Numbers (#11).

E. UNIVERSITY OF HAWAII

We are performing theoretical studies in the following areas:

1. Protocol
2. Carrier Sense
3. Capture Ratio
4. Packet Length
5. Continuation of studies contained in ASS Notes 4 and 26.

Dr. Kahn then delineated the following as some things that are important:

1. Need to look at the antenna problem closely, particularly the use of phased arrays to sum signals spatially for space slotting. Pointed out there may be as many as 10 to 15 stations in a metropolitan area the size of Boston.
2. Need to exercise enough control on the data flow in a crowded area to keep terminals from mutually interfering (like a 30 foot radius).
3. Multipath seems to be the limiting factor in the urban environment.
   a. Kahn does not think it is a fundamental factor.
   b. Kahn wants a close look at it in order to find schemes of overcoming it.
4. Need to look at high density power sources (batteries) to get the size and weight down. There is a need to run as long as possible on a source.
5. Kahn was happy to see that the issue of safety was brought up since it could be a limitation on RF peak power.

Following Bob Kahn's comments, each group presented its material. Since much of the material is contained in the notes, I just took notes on what each speaker seemed to emphasize.

COLLINS

Chuck Vandament emphasized what a problem multipath is and expressed the feeling that lower frequencies may be better. (See note #14).

NETWORK ANALYSIS CORPORATION

They are quite interested in the potential of using cable TV systems for dense urban areas and plan to look into its possible application in connection with a CATV system they are in the process of upgrading to two-way. There will be two cables, one only one-way but the other two-way. The broadcast channels on both cables occupy in the 54-260 MHZ spectrum and the return channel occupies the 5-30 MHZ spectrum on one of the channels. They are looking at grabbing 6 MHZ of spectrum on one outbound channel and6 MHZ on the inbound channel for data.

STANFORD RESEARCH INSTITUTE

Stan Freilich gave an interesting presentation starting with Shannon's Theorem for channel capacity:

$$C = W \log_2 (1 + \frac{Pr}{N_0 W})$$

He pointed out it is important to consider cost/PK P_{wr} versus cost/BW. To escape the peak power limit you can try multiple frequencies:

$$C_i = \frac{W}{n} \log_2 (1 + \frac{P_r n}{N_0 W}) \qquad n = \# \text{ of frequencies}$$

$$\sum_i^n = W \log_2 (1 + \frac{P_r n}{N_0 W})$$

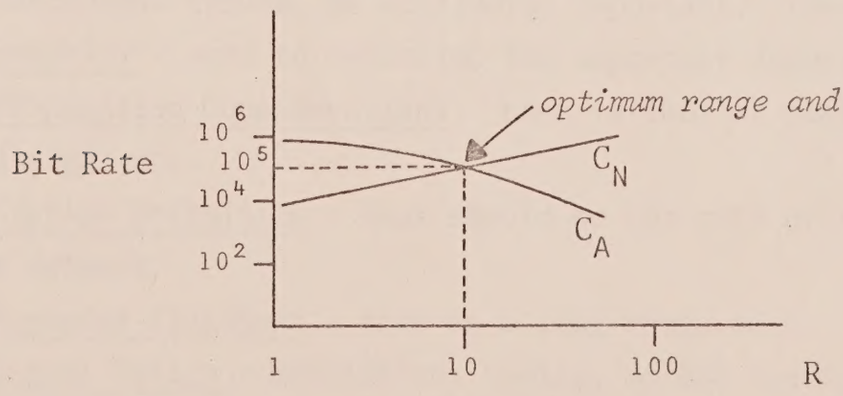
As you can see the power has been spread over the n frequencies. To find the range to which you can optimally operate, let:

R = radius
δ = density (terminals/mi.^{2})
S = source bit rate
μ = 1/e

Then: $C_N(R) = \pi R^2 \delta \frac{S}{\mu}$

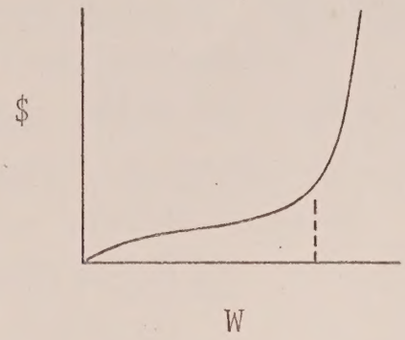
and: $C_A = W \log_2 (1 + \frac{P_r}{N_0 W R^4})$ (assuming $1/R^4$ spreading loss)

Assuming a 10 to 13 dB C/N ratio and plotting these curves, you get:

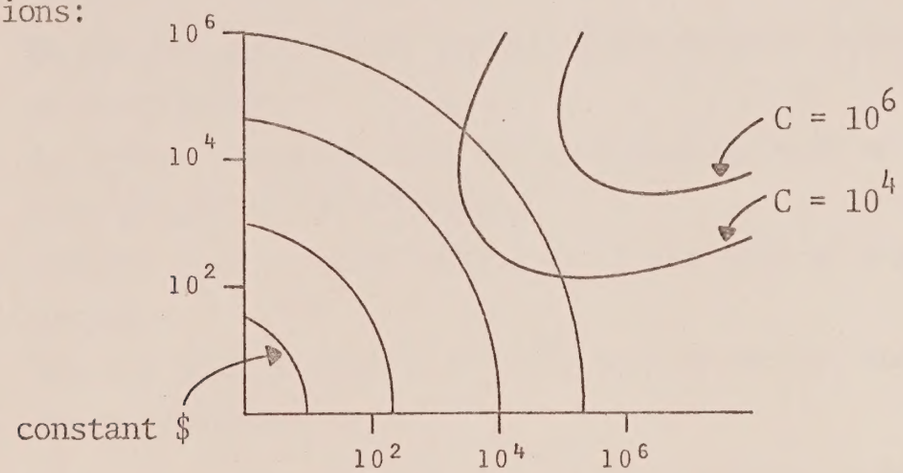


The result looks like 10^5 BPS and 10 miles are optimum. This result is in good agreement with Terry Cory's analysis (note #4).

Stan is now looking at cost tradeoffs. If you assume some sort of limiting cost versus bandwidth curve, such as:



Then you can draw constant cost curves and constant capacity (rate) curves on the S/N ratio versus bandwidth plane and look for the intersections:



Stan thinks carrier sense would be very helpful.

Following all the presentations and discussions, Dr. Kahn presented a set of tasks (conceptual issues) he considered important. These are as follows:

(1) Security - need to determine the important issues.

(2) Propagation Considerations - need to look at peak power, antenna design, etc.

(3) Station Definition - what should be the role of the station in a network.

(4) Repeater Placement - this is a long range task.

(5) Signal Design - modulation, coding, spread spectrum, capture, doppler.

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(6) Operational Characteristics - design, maintenance, testing, measurement. (This task is directed mainly at repeaters.)

(7) In-building Considerations - this task is of major importance.

(8) Auxiliary Resources - distribution lists, location information, directories, access to accounting resources, etc.

(9) Error Control and Recovery - this includes the problem of network recovery from fault conditions.

(10) Airborne Packets - terminals located in airplanes.

(11) Hand-Held Terminal Considerations - general considerations directed toward the human interface problem.

(12) User Requirements (Traffic)

(13) Component Considerations

(14) Theory

Some discussion followed the presentation of these tasks with the resulting points being made:

(1) We are not yet able to decide on the network form, whether centralized or distributed.

(2) At the next meeting, the decision must be made on whether to go hierarchial or distributed.

(3) Someone needs to carefully look at the role of stations in the system.

(4) The key variables must be defined, written up, and presented at the next meeting.

In order to best obtain progress on solving these problems, Kahn set up study groups for the above tasks and various members of the group volunteered to work on different tasks. Bob Kahn will distribute a note soon, showing who is on what task. The assignments were made on the basis of individuals who are directly involved in the Packet Radio group. As for our participation, Dave Wax is assigned to Propagation Considerations (#2) and Norm Abramson to Signal Design (#5). Although Tom Gaarder will probably be looking at the signal design, Norm was put down as contact man. Dave Wax is also assigned to Operational Characteristics (#6).

David W. Wax

January 29, 1973